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WEST VIRGINIA UNIVERSITY
AGRICULTURAL EXPERIMENT STATION,
MORGANTOWN, W. VA.

BULLETIN 74. MARCH, 1901.

Cold Storage.

BY L. C. CORBETT.

[The Bulletins and Reports of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of Agricultural Experiment Station, Morgantown, W. Va.]

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Cold Storage.

The commercial production of apples and pears, and the low price consequent upon forcing the crop upon the market at harvest time, has awakened an interest among growers, as well as dealers, in fruit storage. One of the first questions to be settled in such an industry is, where can the fruit be most economically and profitably held? There are manifestly two logical answers. The producer will say the fruit can be held on the farm more economically and profitably than in the city. The dealer will undoubtedly answer, from his standpoint, that the fruit can be most profitably stored in the city. Both these replies are true from the view-point of the persons making them, but since we are chiefly interested in the welfare of the producer we will discuss it from his view point—that in the long run there is most to be gained by storing the product on the farm.

The question then arises—

(1.) What is the least annual product that will warrant the expense of erecting a storage warehouse?

(2.) What style of house is most satisfactory for the grower with limited means and a small product?

(3.) At what temperature must the store room be maintained to prove satisfactory?

(4.) What loss may be expected from shrinkage and decay?

(5.) How much of an advance over the price at harvest time can be expected on stored fruit?

1. What is the least annual crop that will warrant the expense of erecting a storage warehouse?

To answer this question satisfactorily involves an inquiry based on query 5—How much of an advance over the price at harvest time can be expected on stored fruit? These will, therefore, be considered together.

It can be put down as an axiom that the lower the price of fruit at harvest time the greater will be the profit from storing it. The season of 1896 is a case in point. Growers in West Virginia were offered only 50c. a barrel for the fruit, and only 75c. to 80c. per barrel for fruit and package combined. Those who had courage to put their fruit in storage and wait results, received a handsome reward. The fruit which was commanding 75c. per barrel at harvest time left the warehouse in April for, none less than, $2.00 per barrel while much brought $3.00 and $3.50 per barrel. At such rates a very small crop would warrant one in investing in a storage house. Such returns are phenomenal, however, and should not be taken as a basis for our calculation. The year 1898 may perhaps be taken as an average. At harvest time apples were worth as high as $2.25 per barrel in the orchard, a few even being sold for $2.50, yet this same fruit held in storage until March and April went on the market at from $4.00 to $4.50 per barrel.

The range of prices paid for apples from the end of the picking season to the end of the storage season for the years 1896 to 1900, inclusive, is sufficiently illustrated by the following table compiled from the weekly market reports on the Baldwin apple for New York City as published in the American Agriculturist:

Month.	Season of—				
	1896-7.	1897-8.	1898-9.	1899-00.	1900-01.
Nov. 1......	$1.00	$1.50 to $2.00	$2.50 to $2.75	$1.25 to $2.00	$1.25 to $1.50
Dec. 1.....	.85 to $1.00	2.50 to 3.00	3.00 to 4.00	1.25 to 2.25	2.00 to 2.50
Jan. 1......	1.00 to 1.12	2.00 to 3.50	3.00 to 3.50	2.00 to 2.75	2.75 to 3.00
Feb. 1......	1.00 to 1.50	2.50 to 3.75	4.00 to 4.50	3.00 to 3.50	1.75 to 3.25
March 1....	1.25 to 1.50	2.50 to 3.50	2.50 to 4.50	2.50 to 3.50	2.25 to 3.50
April 1.....	1.25 to 1.50	2.50 to 3.50	4.00 to 4.50	3.50 to 4.25	
May 1	1.50 to 2.50	2.75 to 3.75	3.75 to 4.50	4.00 to 4.75	

Ben Davis ranged higher at the close of the storage season, but as it was difficult to get consecutive reports of that apple the Baldwin was chosen instead.

In general, if 50c. increase per barrel over the price at harvest time can be calculated on, storage on the farm will be profitable. Experience has so far given a wider margin than this,—averaging about $1.00 per barrel advance year in and year out. If, then, $1.50 apples can be held and put on the market at $1.00 advance, or $2.50 per barrel, it can not but prove a profitable investment. A $1.00 advance on a $1.50 investment is 66⅔ per cent. on the investment,—a very respectable interest. Say that 50 per cent interest may be expected, and that the shrinkage is 10 per cent, then there is 40 per cent clean profit, which gives us a rate for computing the minimum crop which can be stored at a profit.

Let us start out with the following case: A house which will hold 1,000 barrels, costing $2,500,—1,000 barrels of apples worth $1,500, returning a net profit for storage of the 40 per cent found to be an average gain, would return $600 as the interest for one year on a $4,000 investment, which is a rate of 15 per cent, while if based only on the cost of the house it would be 24 per cent interest. This is probably as small a crop as one could afford to build a house for and make it profitable. Yet when the capacity of the house is increased the cost per barrel of storage capacity is lessened, so that the larger the crop the more profit there is in holding it, as a rule. For instance, a house holding 10,000 barrels can undoubtedly be constructed for $8,000.00. This more than cuts the above estimate in halves. To value the fruit at $1.00 per barrel and a profit of 40 per cent would give an increase of $4,000, or 50 per cent of the cost price, in a single season. With such figures before us one conclusion only can be arrived at—that storage houses on the farm will pay, and that they can be made profitable for a crop of 1,000 barrels, either as a co-operative or individual enterprise.

In localities where field stone are plentiful a satisfactory, durable and moderate cost house can be built in the form of a bank cellar by using these stone in cement, making a grout wall. Such a wall can be constructed by unskilled workmen if properly laid out in the beginning. The plan to follow is to use broad 2-inch planks held in place by substantial staging to form a box having a width of the thickness of the desired wall,—say 18 or 22 inches. Into this box lay the dry stones, arranging them somewhat if large, but if small they may be thrown in with a shovel. Put in a layer 6 to 10 inches thick, then pour in *thin* mortar composed of good lime and cement until the box is filled sufficiently to imbed the stone. Repeat the operation, moving the planks upward as the mortar sets until a wall of desired height has been built. I have seen silo walls built in this fashion which were 22 feet tall, and were as solid as one continuous stone when completed. The mortar must be thin and rich in lime or cement. Lime will answer, but it is slower to set than cement, and for that reason less desirable. Such a wall can be built for about one-half the cost of the ordinary rubble wall, and will answer in every way as well.

Ample means of ventilation must be provided in order that nature may be turned to assistance in reducing the temperature of the house as much as possible. Sewer pipes leading for some distance under ground and provided with proper stops or dampers can be very effectively used to assist in reducing the temperature during frosty nights. In addition to this the second story of the house should be provided with one or two ice rooms according to the width of the house. I am inclined to favor two narrow ice rooms, one at either side of the building, with the storage room between and below the ice rooms. See plan and side elevation of such an arrangement, Figs. 1, 2, and 3 :

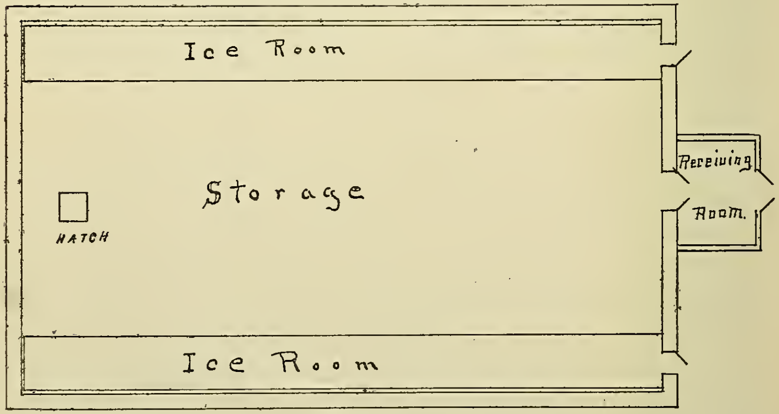

FIG. 1.

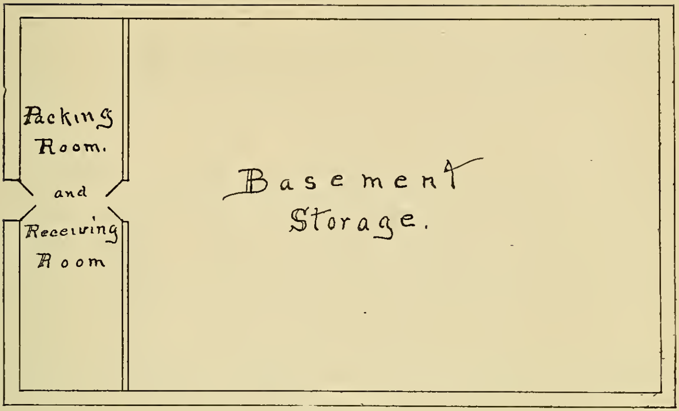

FIG. 2.

The stone wall must have a lining in order to provide a dead-air space between it and the storage room. This can be secured by placing 2x4 studding against the stone wall, covering this with a durable waterproof paper placing 1-inch strips outside of this and covering all with flooring. This will give two small air spaces between the stone or brick wall and the storage chamber. See Fig. 3, cross section of such a wall. The ice chambers should extend the whole length of the building or store room. They may be as narrow as six feet, but eight feet will increase their capacity and cooling power. The floors in these rooms should be made of metal overlaid with 2x4's set on edge, the metal floor so arranged as to allow a free passage of air from the ice chamber into the storage room. As cold air naturally falls the slat floor in the second story wareroom will give direct circulation into the lower wareroom, and both be cooled in consequence. The floor structure must be strong and well braced so as to carry the heavy

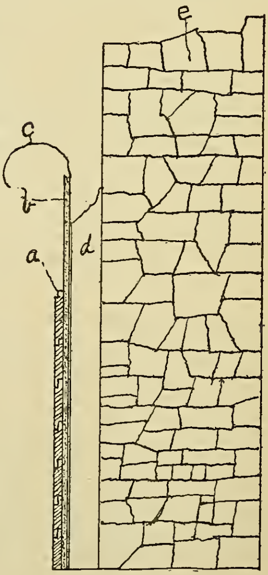

FIG. 3.

a—Flooring.
b—Furring strip.
c—Paper.
d—2x4.
e—18-inch stone wall.

load placed upon it. Heavy staging carrying 2x12 joists 18 inches apart and floored with 2x4's one inch apart will give ample support for the ice chambers and second story wareroom. The roof to the second story room should be built so as to make it as near a non-conductor of heat as possible. Dead air spaces are the cheapest and most easily constructed non-conductors. This is essential in the ceiling as it has the double duty to perform of holding the cold in and keeping the heat out. A large, well ventilated attic space should be provided and, if possible, a shingle or slate roof used in place of metal. The ceiling in the second story must be provided with ventilator shafts carrying good dampers so that perfect ventilation can be secured during cold weather. Provisions should be made the winter before for sufficient ice to cool the warerooms each fall before the fruit is brought in from the orchard. This will necessitate the construction of a reservoir and ice house with capacity sufficient to fill the ice chambers. It is not advisable, in my judgment, to use the ice chambers as ice houses for storing ice; they are merely ice chests to be used to cool the warerooms and fruit as it comes from the orchard. Consequently they can be made much smaller than would be necessary were they to serve the double purpose of cold chamber and ice house.

Apples in Cold Storage.

The time at which fruit should be harvested to give best results in the store house is a much disputed point among storage men. I am inclined to believe that until the question is taken up scientifically and all the factors of climate, such as rainfall, sunshine, together with the physical properties of the soil, and the variety under consideration, are taken into account, no satisfactory answer to this question can be given. As it now stands, experiments with early and late picked fruits conducted at the Ohio Experiment Station and recorded in Bulletin 11, 1889, show that early picked fruits are better keepers than late picked specimens of the same variety. The details of the test are as follows :

RESULTS.

"1. No difference in keeping qualities between early and late picked fruits was manifest at the expiration of two months from date of picking.

"2. Baldwin, Roxberry Russet, and Jonathan showed a difference in favor of early picking. Newtown Pippin and Ben Davis did not exhibit a difference between early and late picking until after the expiration of 6 months.

"3. After the expiration of six months the difference between early and late picking increased until the close of the experiment."

The following table copied from the report gives a summary of results. Whole period seems to be 256 days.

100 fruits in each lot at beginning of test.	Lot A. picked Sept. 26, No. sound apples 227 days after.	Lot D, picked Oct. 20, No. sound 203 days after.	Lot A, picked Sept. 26, No. sound at close of test.	Lot D, picked Oct. 20, No. sound at close of test.
Baldwin	14	5	3	0
Roxberry Russett........	17	2	5	1
Newtown Pippin..	13	3	13	1
Jonathan................	23	0	11	0
Ben Davis	71	48	44	12

The weighings taken during the course of this experiment indicate that the greater part of loss in weight consequent upon evaporation took place during the first two months of the test.

Practice in cold storage buildings in our State gives a conclusion in direct opposition to the above. Men who are close observers and successful growers inform me that the later the Willow and Rome Beauty can be placed in storage without being actually frozen on the trees the better they keep in the store house. These two opinions are each undoubtedly true for the varieties in question, but until this is settled in a satisfactory manner best results cannot be hoped for from cold storage.

The question of the proper temperature at which to maintain the store room in order to get best results is equally as little understood. Neither the manufacturers of refrigerating machinery nor managers of cold storage warehouses have any well grounded reason for the temperatures at which various products are kept. Apples are stored at temperatures ranging from 30 to 40°, some maintaining that the lower point is the only safe temperature while another will maintain that 40° is safer and equally satisfactory in results. Among those using mechanically cooled houses 32 to 34° F. is a common temperature, while with those storing in ice-cooled houses and warehouses 34 to 40° is more common. Equally good results seem to follow from both practices, so it becomes very difficult to decide which is best from such reports.

Tests in an Ice-Cooled House on the Farm.

Through the kindness of Hon. Wm. F. Brown, of the firm of Chas. Brown's Sons, Arroyo, W. Va., I am able to report the results of holding apples in headed and unheaded barrels from harvest time until marketed. The variety used in this test was Willow, an apple of high repute for its keeping qualities. Two barrels were chosen Nov. 4; one was allowed to remain as it came from the orchard, the other had the head removed. They were held in the same room and weighed on the same scales. The weights were as recorded below:

TABLE II.—*Apples in Cold Storage—Headed and not Headed Barrels.*

Date.	Weights.		Date.	Weights.	
	Barrel with head.	Barrel without head.		Barrel with head.	Barrel without head.
	Lbs.	*Lbs.*		*Lbs.*	*Lbs.*
Nov. 4	139½	139½	Jan. 8	136	136
11	139½	139½	22	136	136
18	139½	139½	Feb. 5	136	136
25	138	139	19	136	136
Dec. 11	136½	138½	Mar. 5	136	136
25	136	138	19	136	136
			Apl. 2	135½	135

Along with the record of the change in weight a record of the atmosphere as regards temperature and humidity was also kept by using the standard U. S. Weather Bureau pattern of wet and dry bulb hygrometer. The record for the period is shown in table III.

TABLE III.—*Temperature and Humidity.*

Date.	Dry.	Wet.	Per cent moisture.	Date.	Dry.	Wet.	Per cent moisture.
Nov. 4	49	48	93	Jan. 8	33	33	100
11	48	46	86	22	33	33	100
18	45	43	85	Feb. 5	33	33	100
25	37	35	82	19	34	34	100
Dec. 11	33	33	100	Mar. 5	33	33	100
25	33	32½	95	19	32	32	100
				Apr 2	32	32	100

This table coincides with the results above quoted from the Ohio Experiment Station in showing that the period of greatest loss in stored fruit is during the first month of the storage period. In our tests this is easily accounted for, because prior to December 11th the record indicates that the humidity of the air of the storage room was at no time up to 100, *i. e.*, saturated. While after that and during all the period, over which practically no loss occurred in the weight of the fruit, the atmosphere showed 100 per cent. moisture. This is as might be expected.

A surprise awaited us in this test, however, for in comparing the loss of weight of the headed and unheaded barrels, it was found that loss was more rapid in the headed barrel while the aggregate loss was less. It will be observed that on December 25th the headed barrel weighed 136 lbs., while the unheaded barrel stood at 138 lbs.; fourteen days later, however, January 8, 1900, the two stood the same and continued in that relation until packing began April 2nd, when the headed barrel stood ½ lb. ahead of the other in weight.

The total loss during the period of 150 days was 4 lbs. or 2.8 per cent. of the total placed in storage for the barrel with head in, and 4½ lbs. or 3.2 per cent. of the quantity placed in storage for the barrel with head out.

The following data was obtained from experiments conducted in the cold storage warehouse of Rothwell, Lovett & Co., at Martinsburg, W. Va. I here take pleasure in acknowledging my obligations to the above named gentlemen, and to Mr. F. M. Yerrick for their co-operation and assistance in carrying out this experiment. The house in which this work was carried on is one of three houses of the kind in th United States. The temperature of the storage chambers is maintained by a direct current of cold air instead of by coils of pipe through which chilled brine is forced. In principle the system is the same as that used in the hot air system of heating, except that a coil of chilled pipes take the place of the heater, and the air is used over and over again without renewing. An exhaust fan is used to draw air out of the cold chamber, reduce its temperature and again send it on its round to the cool room. The chief advantages of this over other systems seems to be in lessened expense for piping, remoteness of storage room from refrigerating machinery, and what seems most important of all, a uniform temperature in all parts of the storage room, thus obviating the loss of material which comes from the freezing of fruit stored too close to the coils when the temperature is maintained by the use of circulating brine. In fact, it is claimed that fruit is never frozen under this system.

EXPERIMENTS.

The work recorded here was undertaken for the purpose of determining what, if any, difference in weight or keeping qualities would result from holding apples of the same varieties in sealed darkened jars, sealed clear glass jars, and fruit on the open shelf in dark chambers and in light chambers. The same varieties were selected for each of the four conditions. Each specimen was carefully weighed on delicate chemical balances at the beginning of the experiment and at intervals from December to April, with the following results:

DARK CHAMBER.

Open Shelves.			Sealed Glass Cans.		
No. 1.—Greening.			**No. 30.—Greening.**		
Date.	Weight.*	Loss.*	Date.	Weight.*	Loss.*
Jan. 4	174.642	....	Jan 4	134.937	
15	174.330	.312	19	134.855	.082
Feb. 5	173.605	.725	Feb. 5	134.720	.135
19	173.30	.305	19	134.650	.070
Mar 5	172.520	.880	Mar. 5	134.560	.090
26	171.620	.900	19	134.425	.135
Apr. 20	170.415	1.205	Apr. 20	134.247	.178
Total loss	....	4.327	Total	....	.690

Date.	Weight.*	Loss.*	Date.	Weight.*	Loss.*
No. 2.—Ben Davis.			**No. 31.—Ben Davis.**		
Jan. 4	126.897	....	Jan. 4	114.205	
15	126.650	.247	15	113.910	.295
Feb. 5	126.165	.495	Feb. 5	113.300	.610
19	125.765	.400	19	113.255	.045
Mar. 5	125.315	.450	Mar. 5	113.195	.060
26	124.710	.605	26	113.105	.090
Apr. 20	123.847	.863	Apr. 20	112.972	.123
Total loss	....	3.060	Total loss	....	1.223

*Weights are given in grams.

DARK CHAMBER—*continued.*

Open Shelves.

No. 3.—Baldwin.

Date.	Weight.*	Loss.*
Jan. 4	163.621	
15	163.125	.496
Feb 5	162.5	.625
19	161.190	1.310
Mar. 5	160.85	.340
26	159.55	1.300
Apr. 20	158.257	1.293
Total loss.		5.364

Sealed Glass Cans.

No. 32.—Baldwin.

Date.	Weight.*	Loss.*
Jan. 4	135.180	....
15	135.125	.055
Feb. 5	135.100	.025
19	134.915	.185
Mar. 5	134.850	.065
26	134.755	.095
Apr. 20	134.578	.177
Total		.602

No. 4.—York Imperial.

Date.	Weight.*	Loss.*
Jan 4	139.101	
15	138.980	.121
Feb. 5	138.725	.255
19	138.540	.185
Mar. 5 scald	138.295	.245
26	138.055	.240
Apr. 20	137.635	.420
Total loss		1.466

No. 33.—York Imperial.

Date.	Weight.*	Loss.*
Jan. 4	123.465	
15	123.360	.105
Feb. 5	123.310	.050
19	123.250	.060
Mar. 5	123.190	.060
26	123.080	.110
Apr. 20	122.935	.145
Total loss		.530

LIGHT CHAMBER.

Open Shelves.

No. 10.—Greening.

Date.	Weight.*	Loss.*
Jan. 4	145.925	....
15	145.665	.260
Feb. 5	145.200	.465
19	144.790	.410
Mar. 5	144.310	.480
26	143.560	.750
Apr. 20	142.422	1.138
Total loss		3.503

Sealed Glass Cans.

No. 20.—Greening.

Date.	Weight.*	Loss.*
Jan. 4	116.742	....
15	116.680	.062
Feb. 5	116.615	.065
19	116.555	.060
Mar. 5	116.490	.065
26	116.385	.105
Apr. 20	116.245	.140
Total loss		.497

*Weights are given in grams.

LIGHT CHAMBER—*continued.*

Open Shelves.

No. 11.—Ben Davis.

Date.	Weight.*	Loss.*
Jan. 4	114.161	
15	114.055	.106
Feb. 5	113.795	.260
19	113.630	.165
Mar. 5	113.390	.240
26	113.030	.360
Ap. 20	112.467	.563
Total loss	....	1.694

No. 12.—Baldwin.

Date.	Weight.*	Loss.*
1899.		
Jan. 3	163.120	....
15	162.795	.325
Feb. 5	161.835	.960
19	161.335	.500
Mlr. 5	160.655	.780
26	159.575	1.080
Apr. 20	157.990	1.585
Total loss	....	5.230

No. 13.—York Imperial.

Date.	Weight.*	Loss.*
Jan. 4	143.917	
15	143.810	.107
Feb. 5	143.420	.380
19	143.200	.220
Mar. 5	142.980	.220
26	142.555	.435
Apr. 20	141.948	.607
Total	....	1.969

Sealed Glass Cans.

No. 21 —Ben Davis.

Date.	Weight *	Loss*
Jan. 4	114.327	
15	114.250	.077
Feb. 5	114.175	.075
19	114.115	.060
Mar. 5	114.045	.070
26	113.945	.100
Apr. 20	113.800	.145
Total loss	....	.527

No. 22.—Baldwin.

Date.	Weight.*	Loss.*
Jan. 4	130.792	....
15	130.720	.072
Feb. 5	130.610	.110
19	130.535	.075
Mar. 5	130.455	.080
26	130.340	.115
Apr 20	130.170	.170
Total	....	.622

No. 23.—York Imperial.

Date.	Weight.*	Loss.*
Jan. 4	136.350	
15	136.270	.080
Feb. 5	136.175	.095
19	136.100	.075
Mar. 5	136.025	.075
26	135.910	.115
Apr. 20	135.770	.140
Total loss	....	.580

*Weights are given in grams.

The above tables are pregnant with suggestions. They show most markedly the advantage of storing in *closed* receptacles as against open crates. Barrel headed tightly would naturally be expected to give almost as marked a difference in comparison with open barrels or crates as the fruits in the open in this test gave with those in the glass jars, although tests at the Charles Brown's Sons house above referred to (see page 59,) do not verify this in practice.

While this test does not show the period of greatest loss of weight during the storage season, it does show that there was a constant and very considerable loss of weight in the apples placed on the open shelves, and that the loss was different for the several varieties. In the open the York Imperial lost least, while the Baldwins lost most. This is true in both cases, whether the fruits were kept in the dark or in the light. A very unexpected result is shown by the weights for the light and dark chambers: *the fruit in the light, with the exception of York Imperial, lost least.* This shows that light in itself is not a disadvantage to the stored fruit as might at first thought be expected.

From the beginning of the test up to March 5, 1900, all the fruits kept in perfect condition. At this date, all of the Baldwins showed the effect of a dry rot to some extent. The York Imperial in both the light and dark chambers of the cupboard, as well as those in the transparent glass cans, showed signs of the "scald." From this date forward to the close of the experiment, April 20, both scald and rot increased. On March 26th all specimens of Baldwin showed rot of a dry nature, no soft rot; in addition the York Imperial, in all save the dark sealed cans, as well as the Greenings in the light chamber of the cupboard and the transparent glass can, showed "scald."

There was no change in this record, however, at the close of the test April 20. From this it appears that variety is an important factor in determining the presence or absence of scald. This cannot be taken as a general rule, however, for certain specimens and lots of a variety will scald while others of the same sort in the same room and treated similarly will not. I have an idea that when the true cause for "scald" is discovered it will be a direct result of the physiological condition of the apple when it went into storage. It may be the stage of development, the condition of the atmosphere when barreled, or any one of the several causes influencing the physiological condition of the fruit at the time of storing.

As a rule, however, poorly colored fruits and those naturally having a yellow or green skin are most afflicted by "scald."

The test also shows a predominance of scald in fruits stored in the full light. Under ordinary conditions light plays no part, as all or nearly all storage rooms are quite dark, and if not the fruit is held in headed barrels which exclude the light.

CHEMICAL ANALYSIS.—At the beginning of the experiment a set of specimens corresponding with those to be used in the tests were taken, carefully wrapped in waxed paper, packed in sealed tin cans and sent to the chemical laboratory of the Experiment Station for analysis. The analysis were made by Mr. D. C. Howard, Assistant Chemist, and are as follows:

The figures in table below were obtained upon single specimens analyzed in January and April, and are quite distinct and apart from the analysis in Table V.

TABLE IV.—*Average Analysis of Apples at the Beginning and Close of Tests.*

Variety.	Moisture.		Acidity.		Inv. Sugar.	
	Beginning Jan.	Close April.	Beginning Jan.	Close April.	Beginning Jan.	Close April.
Baldwin	85.1	84.5	0.60	0.373	6.28	6.77
Ben Davis	83.8	86.4	0.53	0.368	6.87	6.21
York Imperial	84.4	84.7	0.43	0.374	8.78	8.32
Rhode Island Greening	83.2	85.5	0.56	0.481	7.09	6.90

From a study of the above table of analysis one is surprised at the remarkably small change which took place in the fruits during the storage period. In fact, the only marked difference is in the decreased acidity at the close as compared with that at the beginning. A slight falling off in the sugar content is also to be observed in all specimens except the Baldwin, where a perceptible increase is noted.

TABLE V.

	Moisture.		Invert Sugar.	
	Jan.	Apr.	Jan.	Apr.
Baldwin	85.0	84.6	7.24	7.44
Ben Davis	85.1	84.8	7.75	7.91
York Imperial	85.0	84.8	8.66	8.78
Rhode Island Greening	85.5	85.2	7.64	7.80

Above analyes made in April and the figures for January obtained by calculation on basis of relative proportions of moisture, no physiological changes therefore being indicated by them.

Table V brings out in a more marked way the changes which actually took place in the specimens under observation. While table IV brings out the changes in acidity, table V clearly shows the loss of moisture and the gain in sugar which might be expected from the advancement of the ripening process while the fruits were in store. These remarks apply only to the apples in the light and dark chambers of the cabinet where the fruits were fully exposed to the air.

The change of moisture content or loss of weight for the fruit in cans is markedly different from those above noted, as will be noticed by consulting the total loss of moisture in Nos. 20 to 33 inclusive, recorded on pages 61-2-3 of this bulletin.

In connection with our work on the chemical changes taking place in the fruits in storage, the following extracts from an article by Gen. S. H. Hurst in Ice and Refrigeration, 1899, are of interest:

"The fact that in most climates vegetable and animal products, where robbed of the principle of life, decay rapidly in warm temperatures, and resist decay in cold atmospheres, had of course been known through all history. But the value of the practical application of that great truth of nature in the affairs of every day life had not been understood or determined until the present generation. But now it has been demonstrated that great store houses holding thousands or tens of thousands of bushels of select fruit can be filled with cold air and so steadily and evenly held at a low temperature and at a given degree of humidity that the fruit in its natural state, charming and beautiful and luscious as it came from the tree or vine, can be kept in almost perfect condition, substantially all the year round. * * * *

"Long ago scientific men determined that the first stage of decay in animal and vegetable matter was a simple form of fermentation. Further along, scientists became convinced that fermentation was a condition of matter produced by the existence and limitless multiplication of infintesimal bacterial life. * * * * The truth became more and more conclusive that these bacteria, by their presence and work, promoted fermentation and decay in all vegetable and animal matter. To defeat the work of these agents of fermentation and decay then became the object of science, and it was first discovered that these organisms could be destroyed by heat, as in the process of canning fruit at boiling heat, and then hermetically sealing it, so as to shut out all living germs, and defeat entirely the march of fermentation, * * * and then followed, like a revelation, the truth that the same end could be accomplished by intense cold, the truth being already demonstrated by experiment that at or near the freezing point all bacterial life was either paralyzed or destroyed; and with other favoring conditions all possibility of fermentation and decay was as certainly defeated, and when these truths were established by practical experiment, then at once was widened to an almost limitless degree the possibility of the preservation of food products through all seasons and in all climates.

Experience has shown that three conditions are necessary to the best results in cold storage of fruits : (1) a low temperature; (2) an even temperature; (3) a certain degree of humidity that will prevent the wilting of the fruit, keeping it plump and crisp, and yet not producing fungus or mould.

The chemical changes that occur during the maturing or ripening of fruits, whether on the tree or while in barrel or bin, are alike simple and beautiful.

If you take a perfect green apple—green simply in the quality of being unripe—and place it under cover in a medium temperature, it will not rot while it remains green. But if you take a ripe apple of the same variety and place it in the same temperature, it will begin to decay at once. And the reason for this difference is quite plain. The green apple is full of starch, and starch does not ferment, but the ripe apple is full of sugar, which does ferment, so that whenever an apple is fully ripe, in ordinary temperatures, its sugar begins to ferment, and the fruit gets over-ripe or decaying. The truth is, however, that starch and sugar are composed of exactly the same chemical elements, but in different proportions, and that the ripening of the apple is but a chemical process, by which the starch of the green apple is changed or transformed into the sugar of the ripe apple by the simple addition of water.

This change is shown by the following equation:

$$\underbrace{C_6H_{10}O_5}_{\text{Starch}} + \underbrace{H_2O}_{\text{Water}} = \underbrace{C_6H_2O_6}_{\text{fruit sugar.}}$$

And it is clear that until the transformation of the starch into sugar is completed by the vital chemical process of ripening, fermentation and decay will not begin.

And now comes the application of that universal law that heat up to a very high temperature promotes fermentation and decay, while cold retards and ultimately defeats them both. Even apples in which the ripening process is substantially completed, when placed in a temperature at or near the freezing point stand for weeks or months without deterioration. On these great truths rests the marvelous value of cold storage, about which the world is just beginning to learn. It may be that there are other forms of ferment beside bacterial fermentation, and it may be that there are other forms of decay beside that of fermentation. But it is none the less true in either case that the preserving power of cold storage can keep the products of our orchards, gardens and fields in perfection through all the seasons and enable us to send them in almost limitless quantities to the markets of every zone."

Chestnuts in Cold Storage.

The improvement of the chestnut, together with the importation of the Japanese sorts, has given commercial chestnut culture an important impetus. The one drawback which seems to handicap the industry at the present time is its comparatively short season in the market. By that I mean that the nut is not fit for use very many weeks after harvesting. Drying renders them hard, difficult to masticate, and of little commercial value.

The idea was conceived that possibly by the use of cold storage the injury to the nuts by insects might be stopped and the sweet, tender kernel so much relished when properly cured might be maintained. Accordingly a quantity of commercial chestnuts, 176 lbs. and 11 ounces, were spread in a rack 4 inches deep 30 inches inches wide and 6 feet long, covered top and bottom with wire screen. After spreading the nuts in the cage it was suspended from the ceiling of 'the cold chamber in which apples were stored. The temperature was maintained at 32° F. Under these conditions the loss of weight was 11 pounds and 3 ounces. The quality of the kernel was maintained in a remarkable maner, and by some the nuts in May were adjudged better than in the fall. The insects, too, were so completely benumbed, if not entirely killed, that they did no damage to the nuts after being placed in store. The following opinions of competent judges are sufficient guarantee of the success of the experiment :

W. A. Taylor, Assistant U. S. Pomologist, Washington, D. C., writes under date of May 4, 1899 :

> We found these chestnuts quite soft and pliable, having the appearance of fresh nuts. They were entirely free from mould, except an occasional specimen. The quality was good, though most of the nuts had a peculiar sweetish taste, similar to that found in nuts that have been slightly scalded, possibly due to fermentation before being put into storage. You do not state what temperature these were subjected to. A considerable portion of the nuts were found damaged by larvæ, though no larvæ were found either in nuts or in the can. Were they stored in large packages or in cans like that

in which these were received? In an experiment on the storage of chestnuts conducted some years ago I found that nuts stored at 30 to 32° Fahrenheit deteriorated very perceptibly between October and April as compared with nuts from the same sources stored at 14 to 16°. The latter were hardly distinguishable in flavor from fresh nuts, and showed a large percentage of germination when planted the following spring. In reply to your question whether such an enterprise could be made a profitable commercial undertaking I would say that in my opinion it is entirely feasible to hold sound chestnuts through the winter in excellent condition and flavor, provided they are stored at a temperature sufficiently low, say about 15° Fahrenheit. Whether a profitable demand exists after the first of March is questionable. My observation has been that the sales of nuts of all kinds drop off quite rapidly as soon as fresh fruits from the south appear in the market at moderate price, and from conversation with dealers and storage men I judge that this has been their experience. I am satisfied that nuts can be held for planting to good advantage in this way, and that the heavy loss which planters often experience when they undertake to grow a large number of chestnut trees can be avoided in this way at small expense.

Professor L. H. Bailey, Cornell University, says:

The chestnuts came while I was away from home. I have now opened them and have made one meal off them. Thev are certainly of high quality. I was surprised to find such good nuts at this time of year. I have not been able so for to find any live worms in the sample.

I am in doubt as to what the prospect is for the commercial cultivation of chestnuts. Much will depend upon how completelv the insects can be centrolled. If the nuts can be kept in good condition until this time of the year they ought to bring a good price. All nuts, not being perishable products, are likely to be very low in price.

C. L. Marlatt, Assistant Entomologist, U. S. Department of Agriculture, Washington, D. C., makes the following reply to our request:

In the temporary absence of Dr. Howard I have to acknowledge the receipt of your letter of the 24th, with accompanying specimens. I have asked Mr. Chittenden to look over the can of chestnuts which you have kept in cold storage. He desires me to inform you that the nuts are, in his opinion, in the best condition, and that their flavor is excellent, better by far than chestnuts when freshly gathered or kept in a dry, warm place. Whether or not the preservation of chestnuts in cold storage would prove a paying commercial undertaking it is difficult to say. It all depends on the demand, or, in other words, whether the nuts could be sold out of season. The nuts show that they were infested to a slight extent by the larva of a species of *Balaninus*, or Nut Weevil. Cold storage has practically no effect whatever upon these insects. The parent beetle, as you may know, deposits

its egg in the growing seed, and the larvæ, attaining full growth in a very short time, issue soon after the nuts are gathered. Normally they transform in the earth, and as they are usually placed in barrels or receptacles from which they cannot escape, they soon perish.

David Rust, Secretary Pennsylvania Horticultural Society, writes as follows:

Some time ago I received a package of chestnuts from Mr. Meehan, which were sent on by you. The can was opened on our meeting day, May 16, 1899, and the report of the Committee on Exhibits was as follows: "'Chestnuts' exhibited by L. C. Corbett, W. Va. Agr. Experiment Station, show excellent preservation by cold storage system, both as to condition and flavor.

Frank Ruppert, New York, in reply to my request for information, writes, April 27, 1899:

The samples of chestnuts which you sent me are at hand, and agreeable to your request I have made inquiries among prominent dealers to learn what they would consider the selling qualities to be, and was informed unanimously that they considered them unseasonable, and consequently without a fixed market value; that in season they bring from $1.75 to $2 a bushel; but these gentlemen would not care to quote a price at this time of the year.

J. W. Thorn & Co., wholesale fruit and produce commission merchants, Philadelphia:

In reply to your favor of the 24th will say the can of chestnuts arrived sent by Mr. Lovett, of Martinsburg, and will have to report to you that there is no demand for them on this market at the present time. It is too late in the season for them here.

Sorry we could not place them for you to good advantage, but we have tried our best people here who use them, and they say there is positively no demand whatever for them.

Somers, Bro. & Co., Pittsburg, Pa., make the following reply to our inquiry:

We have to acknowledge the receipt of your favor of 24th, and can report delivery of your sample can of chestnuts referred to. We find the quality and the flavor of the chestnuts have been well preserved, but regret to state that there does not appear to be a market for them at this season. Dealers who buy largely and regularly in the nut season state that they are unable to make sales so late as this, and will therefore not buy. While the experiment is interesting and shows the preservative qualities of cold storage, so far as our market is concerned, at least, no encouragement can be given for carrying the goods.

The foregoing letters from commission men in New York, Philadelphia and Pittsburg serve to show the present attitude of the market towards an industry of this sort. While discouraging in the extreme, it must not be made to bear the interpretation that such an industry is impossible of development.

The effect of the cold on the chestnut worm in this experiment is a confirmation of the good sense of a practice which is rapidly gaining commercial recognition—that of placing valuable furs, rugs, and articles of wearing apparel in cold storage while not in use during the summer months. The theory is that if the eggs or larvæ of the destructive insects are present even at the time of placing the articles in storage their further development and destruction will at once be checked.

As appears from the above-quoted correspondence, the chief drawback to the success of this enterprise lies not in keeping the chestnuts in good condition, but in finding a sale for them after they have been kept Like all new industries it will have to create its own demand and make its own market. This will limit the profit of the industry to begin with, but the demand will increase as soon as cold storage chestnuts come to be appreciated by chestnut eaters. There is but little doubt that in the course of a few years chestnuts will be as plentiful in the market in March as they now are in November. If the chestnut eaters can be educated to eat them from October to April instead of during November and December only, the season for them will be three times as long, with a corresponding increase in the quantity consumed, which means that commercial chestnut culture can be extended and made more remunerative.

MOISTURE IN COLD STORAGE.

"Besides the temperature in a cold storage room the degree of moisture is of considerable importance.

It is neither necessary nor desirable that the storage room should be absolutely dry; on the contrary, it may be too dry as well as it may be too damp. If the room is too dry it will favor the shrinkage and drying out of certain goods. If the room is too damp goods are liable to spoil and become mouldy, etc. For this reason the moisture should always be kept below the saturation point. This condition can be ascertained by the hygrometic methods described in the chapter treating on water and steam.

There is little danger that the rooms will ever be too dry: on the other hand, they are not required to be absolutely dry, and as to chemical dryers, such as chloride of calcium, oatmeal, etc., they are probably superfluous, with proper ventilation and refrigerating machinery properly applied.

Generally the artificial drying of air is considered superfluous in cold storage, as the air is kept sufficiently dry by the condensation that forms on the refrigerating pipes. In this way the moisture exhaled by fruits, etc., is also deposited. Special care, however, is to be taken to remove the ice from the coils from day to day as it forms, in which case it is readily removeable. Chemical dryers are seldom used in storage houses refrigerated by artificial refrigeration. Freshly burnt lime is sometimes used in egg rooms.

In cold storage houses operated by natural ice, chemical or physical absorbants, such as oatmeal, slaked lime, chloride of calcium and chloride of magnesium are frequently used. The latter substance is the principal constituent of the waste bittern of salt works, which is sometimes used for drying air in the cold storage of fruit.

The waste bittern is spread out on the entire surface of the floor, and, if needed, on additional surfaces above it. One square foot of well exposed bittern, either in the dry state or state of inspissated brine, will be enough to take up the moisture arising from two to six bushels of fruit, varying according to its condition of greenness or ripeness. The floors of the preserving room should be level, so that the thick brine running from the dry chloride may not collect in basins, but spread over the largest surface.

The moisture from the fruit taken up by the absorbent varies from about three to ten gallons for every 1,000 bushels of fruit weekly. The spent chlorides or the spent waste bittern may be revived by evaporation, by which they are boiled down to a solid mass again.

The waste bittern is also used as a crude hydrometer by dissolving one ounce of the same in two ounces of water and by balancing the shallow tin dish containing this mixture on a scale placed in the cold storage room. If the scale keeps balanced, it indicates the proper state of dryness, but if the weight of the mixture increases, the moisture of the room is increasing and the means for keeping the air dry should be put in operation.

Dry Air for Refrigerating Purposes.

To produce a dry air by mechanical means St. Clair considers the entire absence of any condensing or refrigerating surface in the space to be refrigerated absolutely necessary. The rapid circulation of the air in the room is also of vital importance; and in such circulation no contact of the incoming cold air with the outgoing warmair to cause condensation is the result aimed at. To insure these conditions, he places the *refrigerator* at the highest point, and has communicating air shafts from the bottom of the same to the rooms to be cooled. Like shafts ascend from the top of the rooms cooled to top of refrigerator The refrigerating coils in the refrigerator are kept at a temperature of zero to 15° below, and a small stream of strong brine is allowed to drip over the coils to a pan underneath, being pumped back to the upper drips as fast as deposited. This brine will have a temperature ranging from zero to 4° below. The action is said to be simple and effective; *all* moisture is either condensed or frozen instantly as it comes in contact with such low temperature, and absolutely dry air descends in the air shafts to the rooms to be cooled.

Cold Storage Temperatures.

Generally speaking, the temperature of cold storage rooms is about 34° F. For chilling the temperature of the room it is generally brought down to 30° F., and in the case of freezing goods from 10° F. to 0° F.

The temperature and other conditions best adapted for the cold storage of different articles of food, provisions, etc., have been compiled in the following paragraphs, which reflect the views of prominent and successful cold storage men as expressed by them in *Ice and Refrigeration.*

Storing Fruits.

The temperatures for storing fruits are given in the following table:

Fruits.	Remarks.	°F.
Apples		32–34
Bananas		34–36
Berries, fresh	For three or four days	34–36
Canteloupes	Carry only about three weeks	32
Cranberries		33–34
Dates, figs, etc		34
Fruits, dried		35–40
Grapes		33–36
Lemons		34–40
Oranges		36
Peaches		35–45
Pears		33–36
Watermelons	Carry only about three weeks	32

Apples when stored in barrels should not be stored on ends, but preferably on their sides. A temperature of 32° is considered most favorable.

In general, green fruits and vegetables should not be allowed to wither. Citrus fruits and vegetables should be kept dry until the skin loses its moisture, then the drying process should be immediately checked. For bananas no rule can be made. The exigencies of the market must govern the ripening process, which can be manipulated almost at will.

Fruits, especially tender fruits, should be placed in cold storage just when they are ripe. They will keep better than if put in when not fully ripe.

Pears will stand as low a temperature as 33°. Sour fruit will not bear as much cold as sweet fruit. Catawba grapes will suffer no harm at 26°, while 32° will be as cold as is safe for a lemon.

The spoiling of fruit at a temperature below 40° F is due to moisture. In storing apples eight to ten cubic feet storage room space is allowed per barrel, and twenty to twenty-five tons daily refrigerating capacity per 10,000 barrels.

STORING VEGETABLES.

Arrticles.	°F.
Asparagus	34
Cabbage	32–34
Carrots	33–34
Celery	33–35
Dried Beans	52–40
Dried Corn	35
Dried Peas	40
Onions	32–34
Parsnips	33–34
Potatoes	34–36
Sauerkraut	35–38

Asparagus, cabbage, carrots, and celery are carried with little humidity; parsnips and salsify same as onions and potatoes, except that they may be frozen without detriment.

(Chapter VI, Cold Storage, "*Compend of Mechanical Refrigeration*," by J. E. Seibel.)

MATERIALS OF CONSTRUCTION.

"The efficient insulation of a freezing room, or of a cold store or refrigerating chamber, is a matter of very great importance from an economical point of view. This will be apparent when it is remembered that when once the contents of the said cold store or chamber are reduced to the requisite temperature the entire work required of the refrigerating machine will be only that which is necessary to neutralize the heat that passes through the walls, floor and ceiling thereof from the exterior. Consequently, the more perfect the insulation, the less the machine will be called upon to work, and naturally, in a corresponding ratio, also will be the saving effected in fuel, wear and tear upon the working parts and in attendance.

The means adopted for insulation consist in lining the rooms, or, in the case of a marine installation, the hold of the vessel, with some material forming a very bad conductor of heat. The exact method of carrying this out, as also the nature of the non-conducting material employed, must necessarily be considerably varied according to the circumstances of each case. In New Zealand and Australia pumice is much used.

Mr. Lightfoot recommends as a fairly good protection an outer and an inner layer of tongued and grooved boards 1 inch or 1½ inch thick, with a 9-inch space or clearance between them filled with charcoal, or, in some, preferably with silicate cotton or slag wool.

In France and Germany cork is used with marked success as a non-conductor, and it is evidently suitable for the purpose in question, being a material very impervious to heat, and capable of withstanding moisture. Either ordinary cork cut in thin slices or refuse or waste cork from other industries thoroughly ground up or disintegrated into a course powder, is employed, the former being the best but the most expensive.

Various other substances, such as asbestos, cotton wool, sheep's wool, pine wood, loam, gas works breeze, coal ashes, sawdust, hair felt, lampblack. mica, paper, fine cinders, pitch, &c., are likewise employed for purposes of insulation. A number of different compositions have also been tested and used as heat insulators, amongst which may be mentioned the following : Composition of fossil meal, composed of 60 per cent. of washed white German kieselguhr and

40 per cent of binding material; composition of keieselguhr from German mines with 10 per cent of binding matter, such as fibre, and the mucilaginous extract of vegetable; cement composed of blue clay mixed with flax; jute, or woolen waste or cows' hair, in equal proportions; fibrous composition of fine blue clay mixed with flax, hemp, rope, jute, cow hair, and woolen waste; and a papier-mache composition composed of paper pulp mixed with clay and carbon, together with hair and fragments of hemp rope.

In choosing a substance other conditions besides its good insulating powers must be taken into consideration, such, for instance, as its capacity for withstanding moisture. This latter quality is of the utmost importance, inasmuch as at very low temperature moisture from the air is very readily absorbed by many substances, and fermentation, rotting and decay will result therefrom. It is for this reason that cork forms so desirable a material for insulating purposes, although surpassed in non-conductibility by some others. For a like reason pitch, or some form of enamel composed of bitumen or other ingredients, are found very valuable. Lamp-black is claimed to be a very good material for insulating purposes in railway and other portable refrigerating chambers, by reason of its lightness and elasticity, and more particularly on account of its non-liability to pack from jolting, and complete imperviousness to moisture. This material is the one employed by Henry Carr Godell in his patent (1884) moveable refrigerating chamber. When it is desirable to increase the elasticity and reduce the cost, he sometimes uses a mixture of either short fibre or scales of mica.

Whatever the filling material that may be employed for insulating purposes, however, it should always be bourne in mind that the more air that is enclosed with it between the walls or skins the better, for it is a well known fact that the best non-conductor of heat is dry air, the units of heat transmitted per square foot per hour, through a layer of confined air of one inch thickness, being about .29.

The following materials and dimensions have been recommended for walls of cold air chambers:

14 inch brick wall, 3½ inch air space, 9 inch brick wall, 1 inch layer of cement, 1 inch layer of pitch, 2 inch by 3 inch studding, layer of tar paper, 1 inch tongued and grooved boarding, 2 inch by 4 inch studding, 1 inch tongued and grooved board, layer of tar paper, and, finally, an inch tongued and grooved boarding, the total thickness of three layers or skins being 3 feet 3 inches.

36 inch brick wall, 1 inch layer of pitch, 1 inch sheathing, 4 inch air space, 2 inch by 4 inch studding, 1 inch sheathing, 3

inch layer of mineral or slag wool, 2 inch by 4 inch studding, and finally, 1 inch sheathing; total thickness, 4 feet 7 inches.

14 inch brick wall, 4 inch pitch and ashes, 4 inch brick wall, 5 inch air space, 14 inch brick wall; total thickness, 3 feet 4 inches.

14 inch brick wall, 6 inch air space, double thickness of 1 inch tongued and grooved boards, with a layer of waterproof paper between them, 2 inch layer of the best quality hair felt, second double thickness of 1 inch tongued and grooved boards, with a similar layer of paper between them; total thickness, 2 feet 2 inches.

13 inch brick wall, 8 inch layer of sawdust, double thickness of 1 inch tongued and grooved boards, with a layer of tarred waterproof paper between them, 2 inch layer of hair felt, second double thickness of 1 inch tongued and grooved boards, with a similar layer of paper between them, total thickness, 2 feet 4½ inches.

The following table, from experiments by Peclet, gives the amount of heat in units transmitted per square foot per hour, through various substances, in plates or layers of 1 inch in thickness, many of which are suitable for insulating cold air or refrigerating chambers. The experiments were made by heating one side of the plates or layers by means of hot water, and cooling the other side by cold water, the difference between the temperature of the two faces being 1° Fahr. The materials are arranged in consecutive order, commencing at the worst non-conductors, or best conductors of heat.

Materials.	Units of heat transmitted.
Gold	625.
Platinum	600.
Silver	595.
Copper	520.
Iron	230.
Zinc	225.
Tin	178.
Lead	113.
Marble	24.
Stone	14.
Glass	6.6
Terra Cotta	4.8
Brickwork	4.8
Plaster	3.8
Sand	2.17
Oak, against the grain or fibre.	1.7
Walnut, with the grain or fibre.	1.4
Fir, with the grain or fibre.	1.37
Gutta-percha	1.37
India-rubber	1.36
Brick dust, sifted	1.33
Coke, in powder	1.29
Iron filings	1.26
Cork	1.15
Chalk, in powder	.86
Charcoal (wood) in powd'r	.63
Straw, chopped	.56
Coal, powder, sifted	.54
Wood ashes	.53
Mahogany dust	.52
Canvas, hempen, new	.41
Calico, new	.40
Writing paper	.34
Cotton and sheep's wool	.32
Eiderdown	.31
Blotting paper, grey	.26

The quantity of heat units transmitted through one square foot of plate may be found thus : Subtract the temperature of the cooler side from that of the hotter side of the plate, then multiply the result by the number in the preceding table corresponding to the material used, and divide the product by the thickness of the plate. Thus, an iron plate 2 inches thick, having a temperature of 60° on one side and 80° on the other, will transmit

$80-60=\frac{20 \times 230}{2}=2,300$ units of heat per square foot per hour.”

(“*Refrigerating and Ice Making*,” by A. J. Wallis-Taylor.)

HISTORICAL.

Although knowledge of the conservative action of cold upon organic substances is probably as old as the human race, it is only within comparatively recent times that this general principle has been put to practical use for the preservation of foods and for prolonging the period during which they are found in the market. Before the perfection of the modern mechanical means of artificially producing and maintaining low temperatures all preservation by cold was dependent upon a supply of natural ice. Mr. Chas Tellier in 1873 invented a mechanical brine circulating system, by which he was enabled to create a cold, dry atmosphere wherein organic substances could be maintained constantly at that temperature which is found to be preservative. Mechanical cold storage, is therefore, of comparatively modern origin. This invention was first applied to the chilling and freezing of meat, although the preservation of other food substances, such as butter, eggs, fruits, and vegetables was early undertaken. "In 1886 the steamship *Nonpareil* (Scullow, Sons & Co.), which had been fitted for the purpose, brought to the English markets the first cargo of West Indian fruits, and early in 1888 a cargo of apples was shipped from Melbourne in the *Oceana* in chambers also cooled by a Haslam machine, both cargoes arriving in good condition."

L. C. CORBETT.